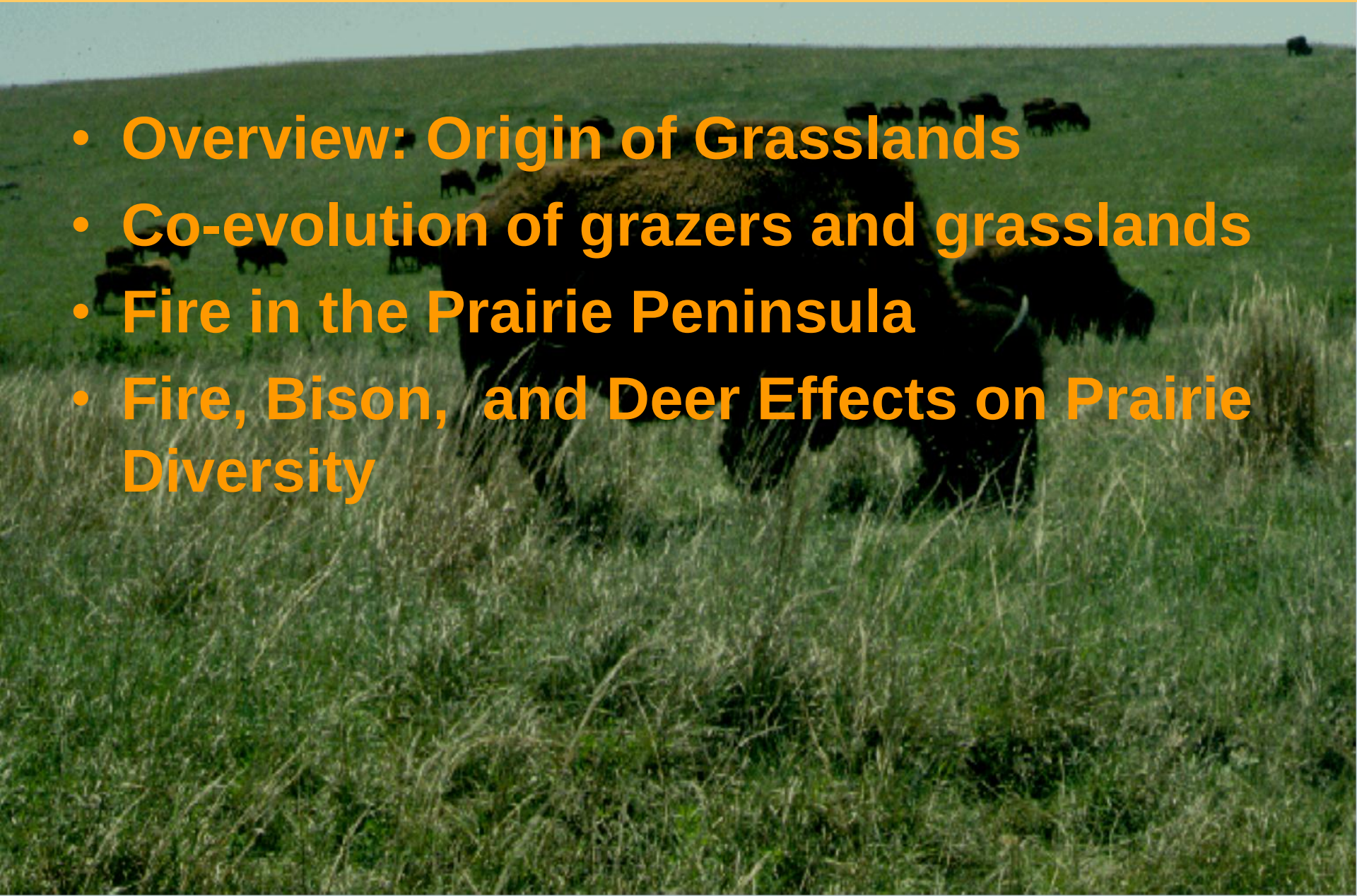
Presentation Outline



- Overview: Origin of Grasslands
- Co-evolution of grazers and grasslands
- Fire in the Prairie Peninsula
- Fire, Bison, and Deer Effects on Prairie Diversity

Common Features of Grasslands

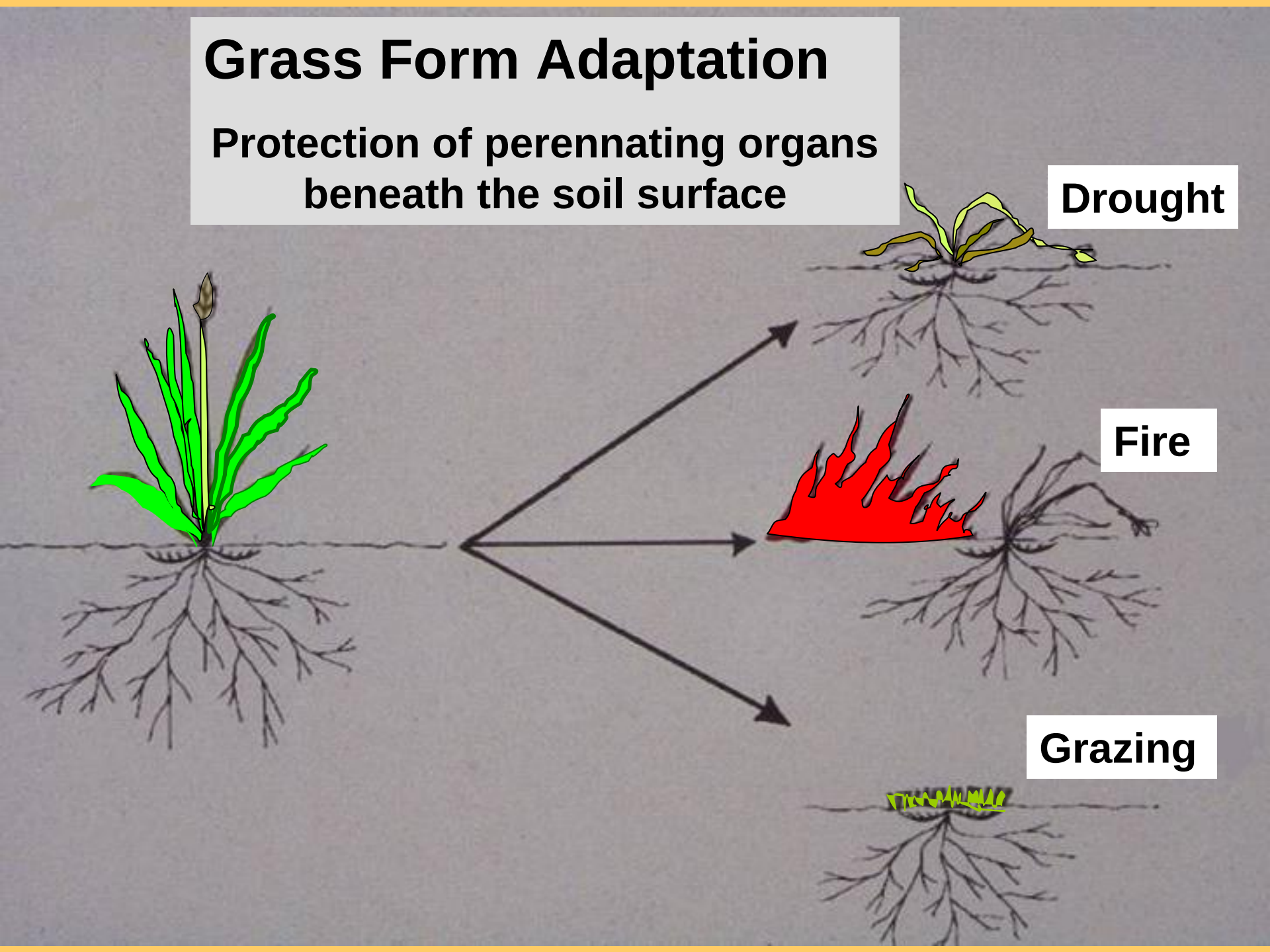
- Periodic droughts and high rates of evaporation
- Periodic fires

Common Features of Grasslands

- Rolling to nearly level landscapes
- Dominance by burrowing and grazing animals

Grass Form Adaptation

Protection of perennating organs beneath the soil surface

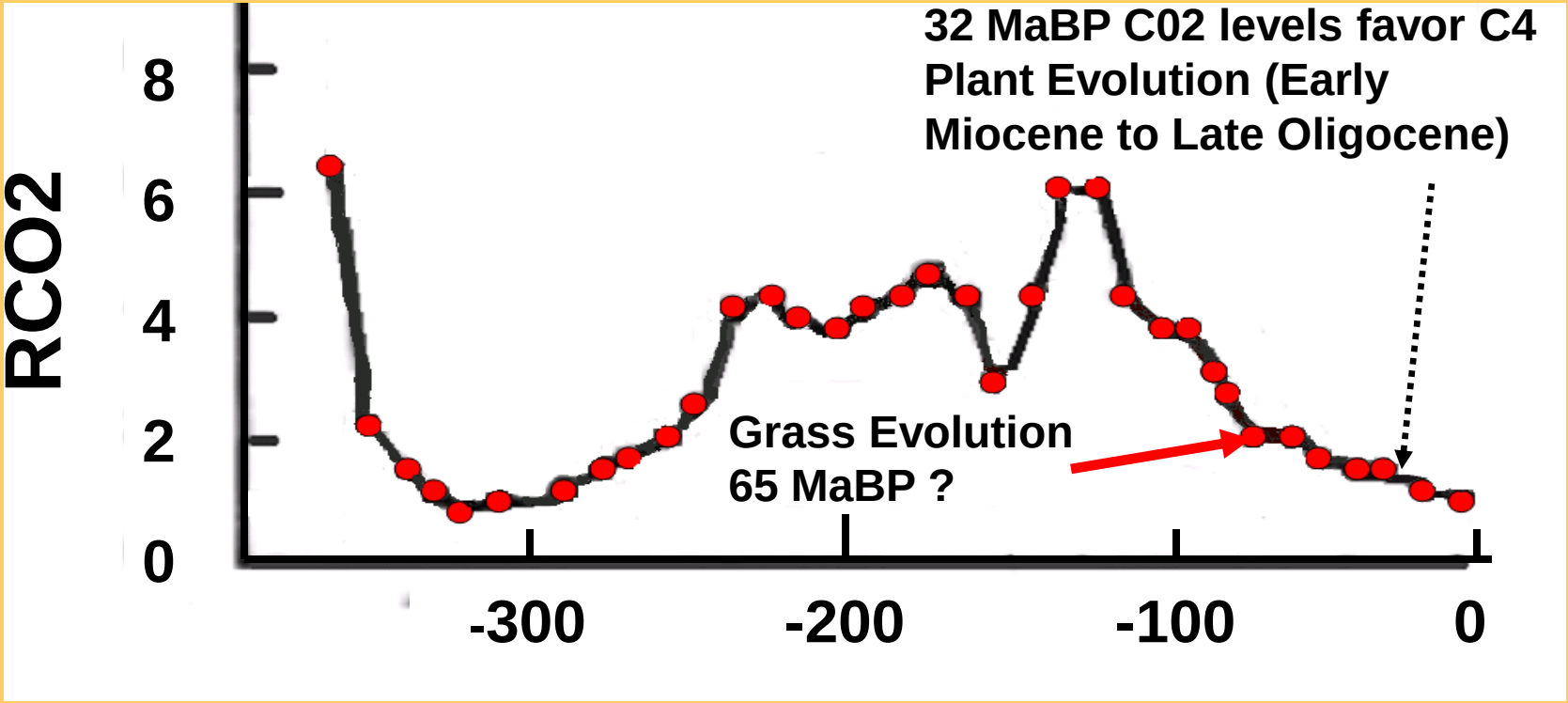


Expansion of Grasslands is related to appearance of C4 Photosynthesis

- C3 Plants
- Cool, moist climates
- Low water use efficiency
- High levels of CO2 > 500 ppm/v
- Low light saturation
- Low photosynthesis rate
- Exhibit Photorespiration

- C4 Plants
- Warm, arid climates
- High water use efficiency
- Selected advantage at low levels of CO2
- High light saturation
- High photosynthetic rate
- No Photorespiration

Atmospheric Carbon Dioxide Relative to Present

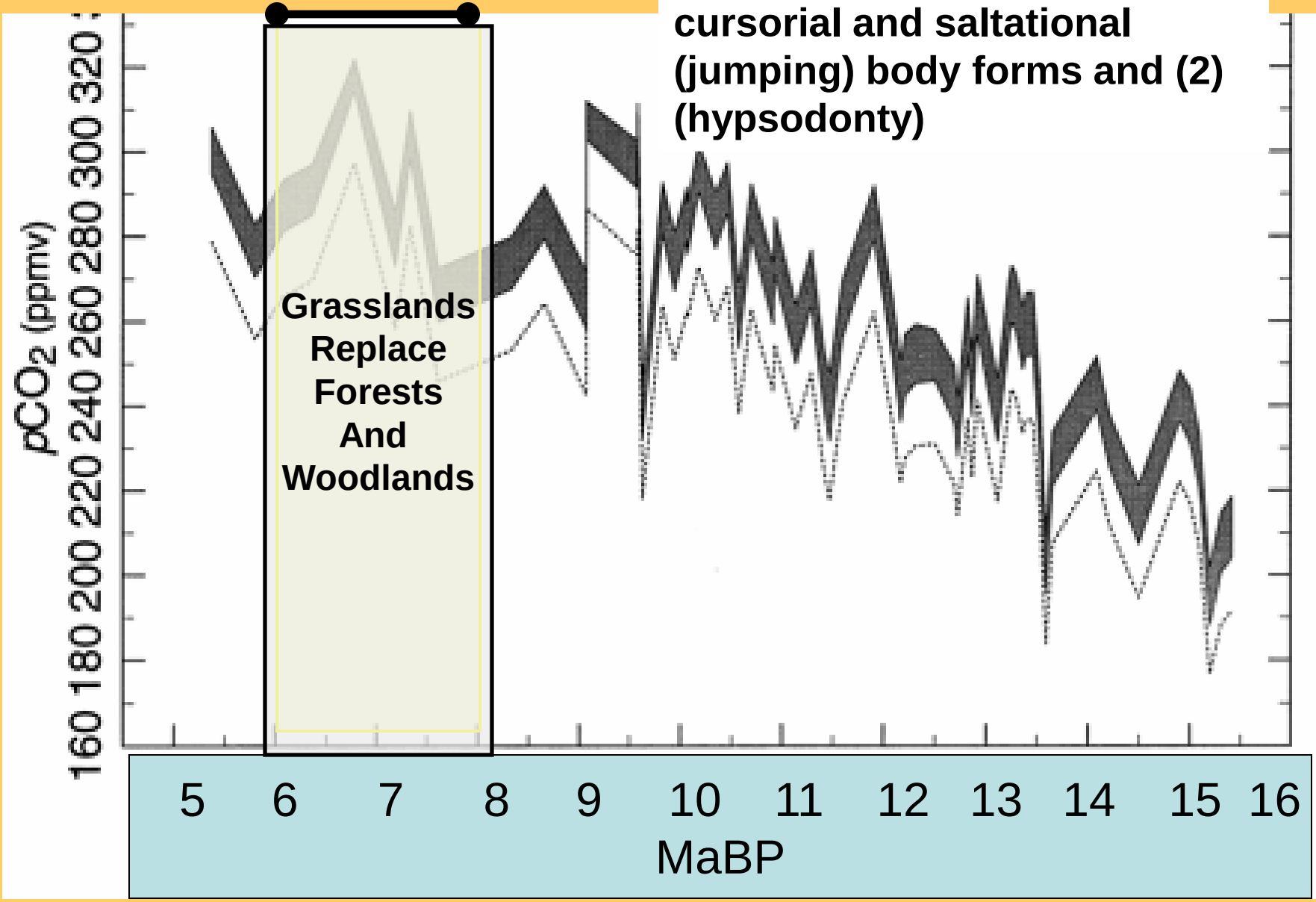


Million Years Before Present

-------Paleozoic----------|--Mesozoic-----|-Cenozoic

Expansion of C4 Plants

Rapid adaptive radiation in grassland animals (1) cursorial and saltational (jumping) body forms and (2) (hypsodonty)

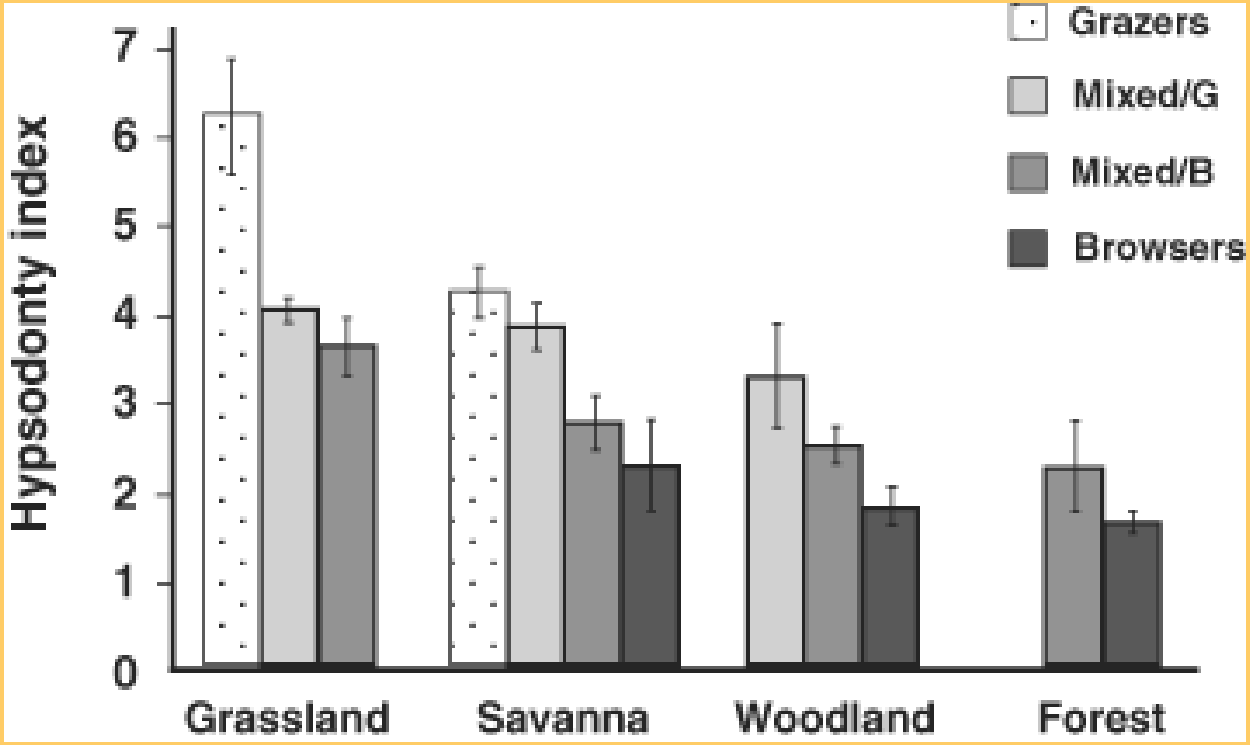


There has been coevolution among grassland organism resulting in many complex interactions

Hypsodonty

- Brachydonty Initial crown emergence complete from jaw
- Hypsodonty delayed complete emergence
  - Initial emergence from the jaw is partial
  - Later emergence as the teeth are worn down
  - High crowned teeth
    - Not necessarily harder
    - Molars and premolars
- Degrees of hypsodonty –
  - Hypsodonty Index = unworn crown length/width or length
- Associated with grasslands –
  - grass has silica bodies
  - Lot of dirt consumption in grasslands
- Paleoecology – relate degrees of hypsodonty to presumed historic vegetation

Relationship of mean hypsodonty index (HI) to diet and habitat type based upon 133 species of living ungulates of known dietary and habitat preference

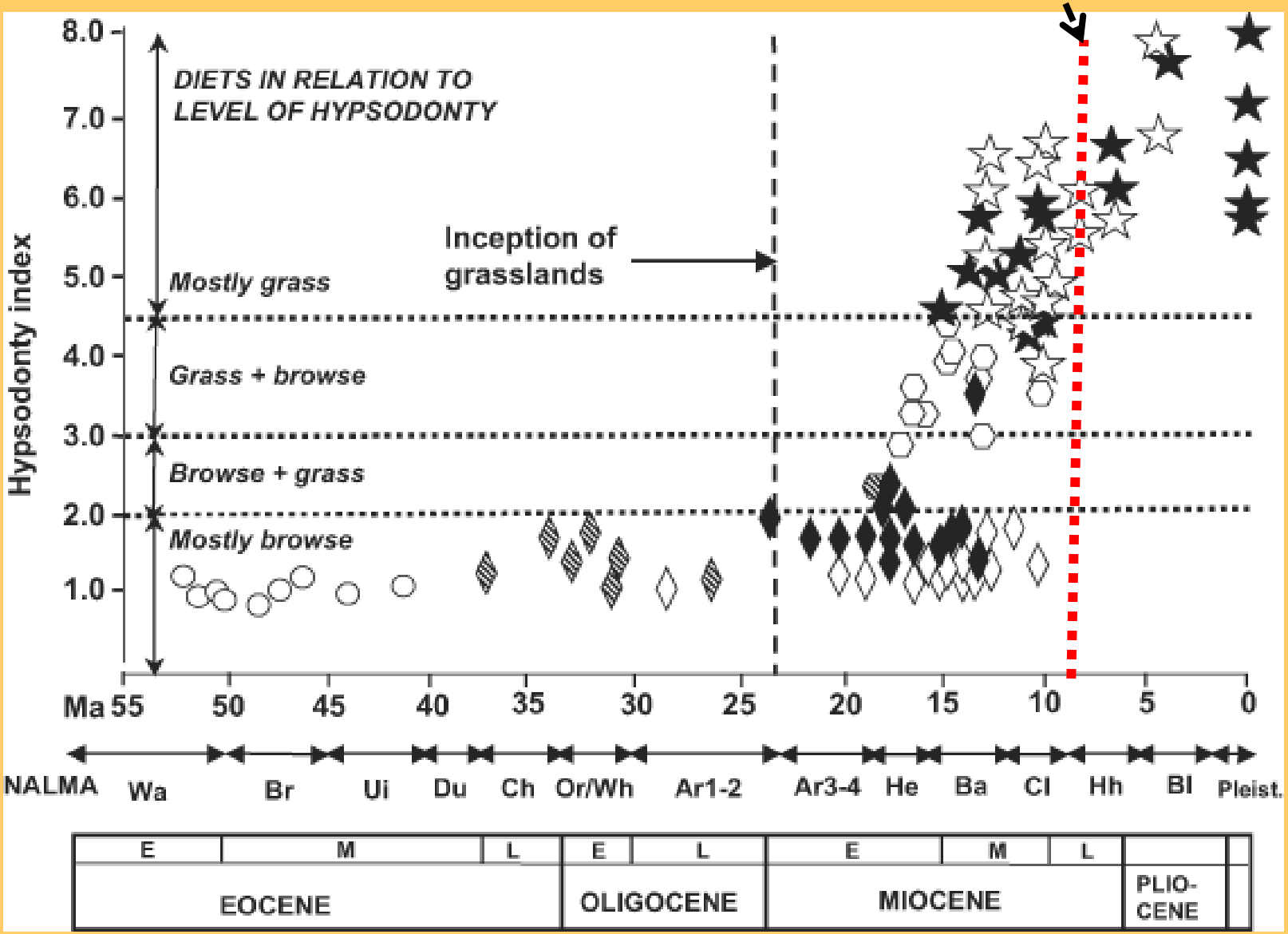


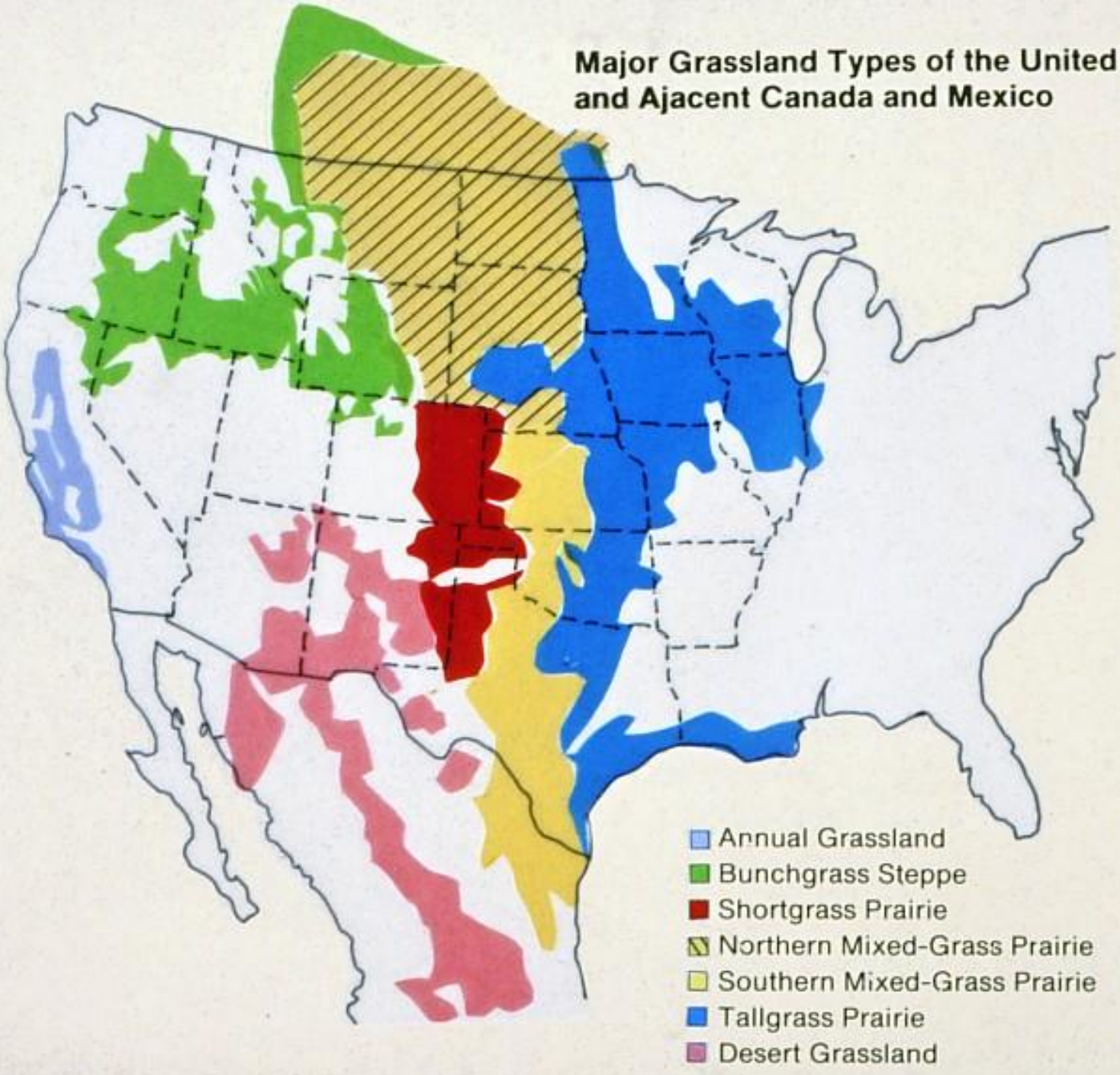
- **Grazer** = ≥90% grass in the diet;
- **Mixed/Grazer (Mixed/G)** = 50–89% grass in the diet;
- **Mixed/Browser (Mixed/B)** = 11–49% grass in the diet;
- **Browser** = ≤10% grass in the diet.

Damuth and Janis. 2011. On the relationship between hypsodonty and feeding ecology in ungulate mammals and its utility in Palaeoecology. Biological Reviews 86: 733-758.

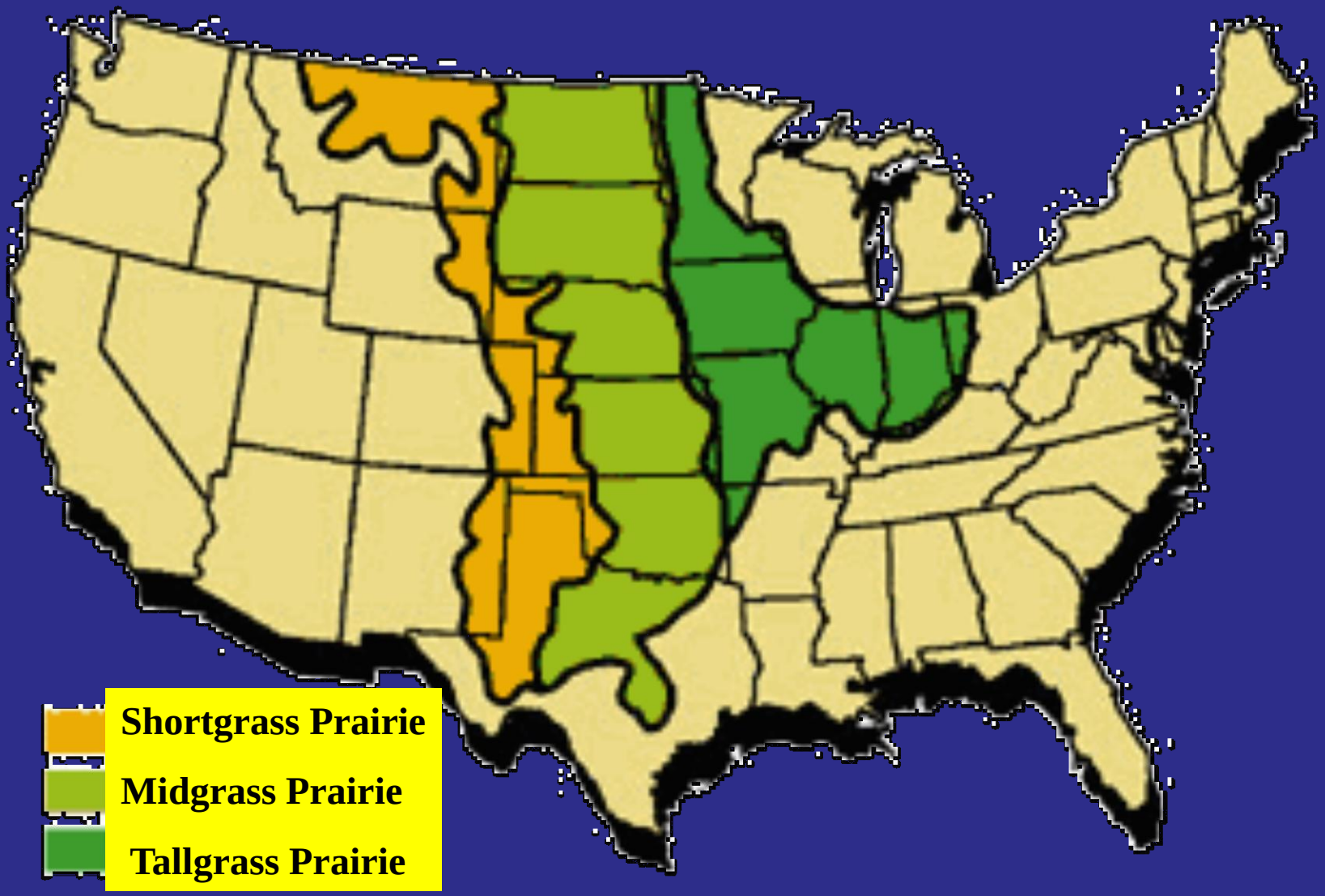
Hypsodonty indices of North American fossil equids (plus Recent Old World equids).

Grassland Expansion & Adaptive Radiation



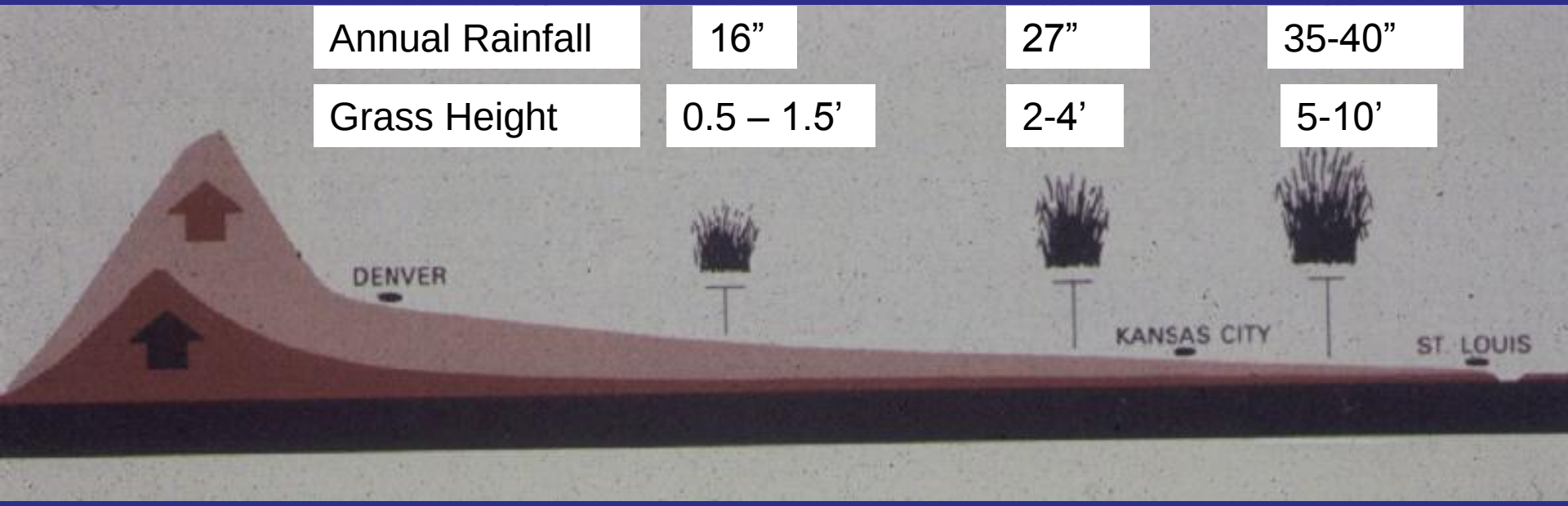

Major Grassland Types of the United States
and Ajacent Canada and Mexico
Annual Grassland
Bunchgrass Steppe
Shortgrass Prairie
Northern Mixed-Grass Prairie
Southern Mixed-Grass Prairie
Tallgrass Prairie
Desert Grassland

Central Grassland



Climate and the Central Grassland

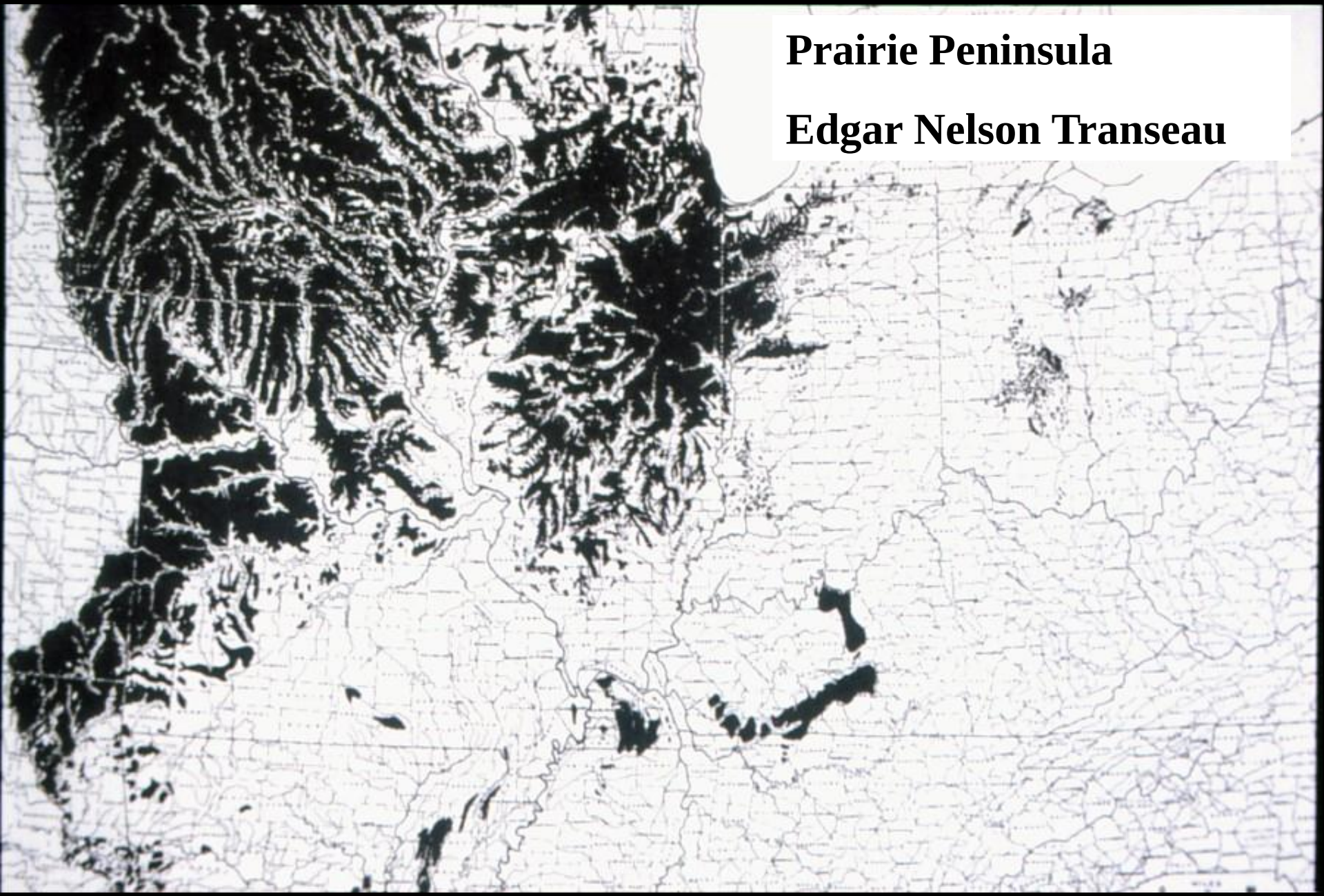
Annual Rainfall	16”	27”	35-40”
Grass Height	0.5 – 1.5’	2-4’	5-10’



Short Grass Prairie

Mid-Grass Prairie

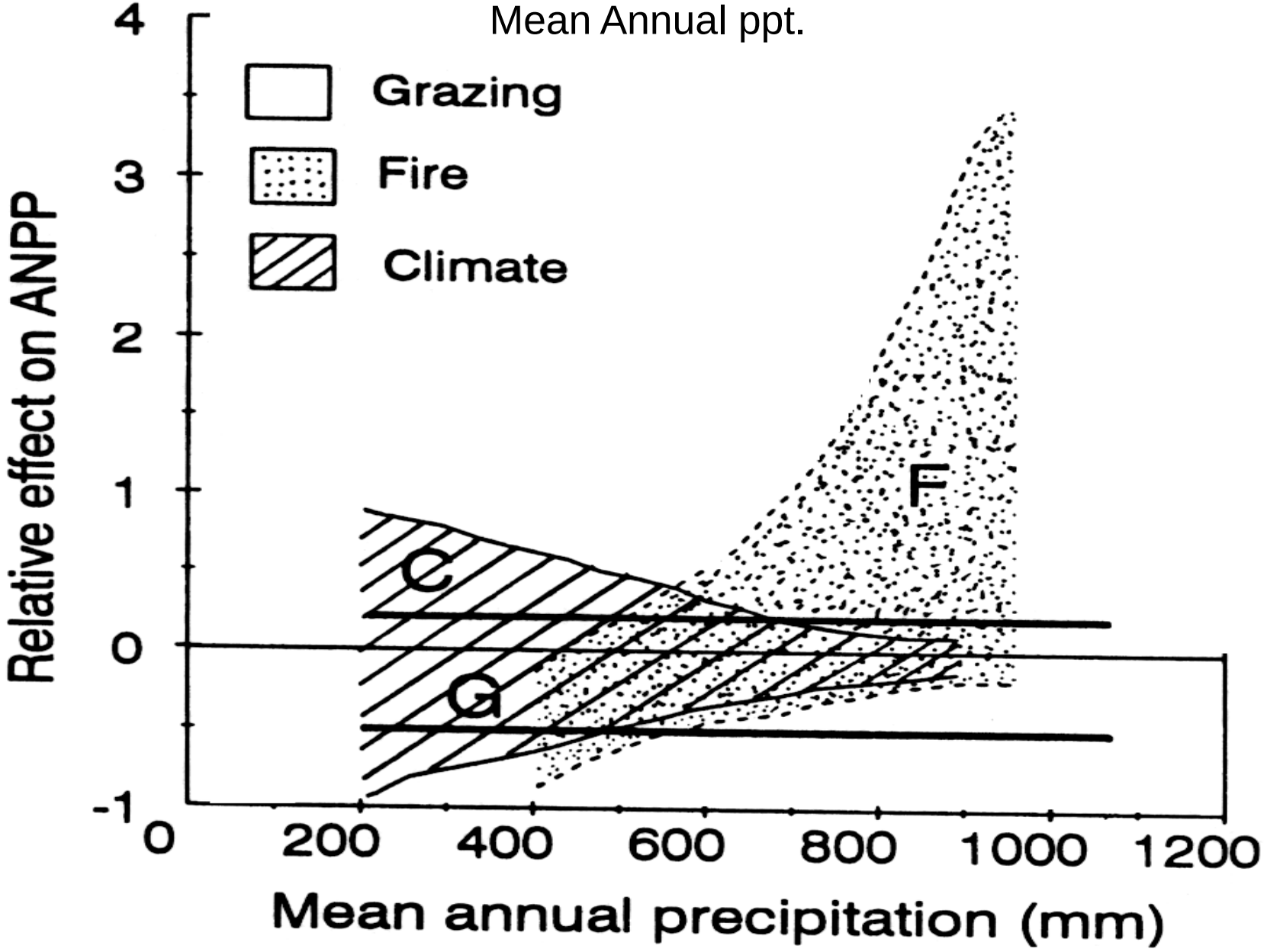
Tall Grass Prairie


Prairie Peninsula
Edgar Nelson Transeau

Fire is necessary for Prairies to Survive

- Control woody plant invasion
- Helps control introduced invasive species
- Increase prairie grass Production

Relative effect of fire, climate, and grazing on ANPP as a function of Mean Annual ppt.

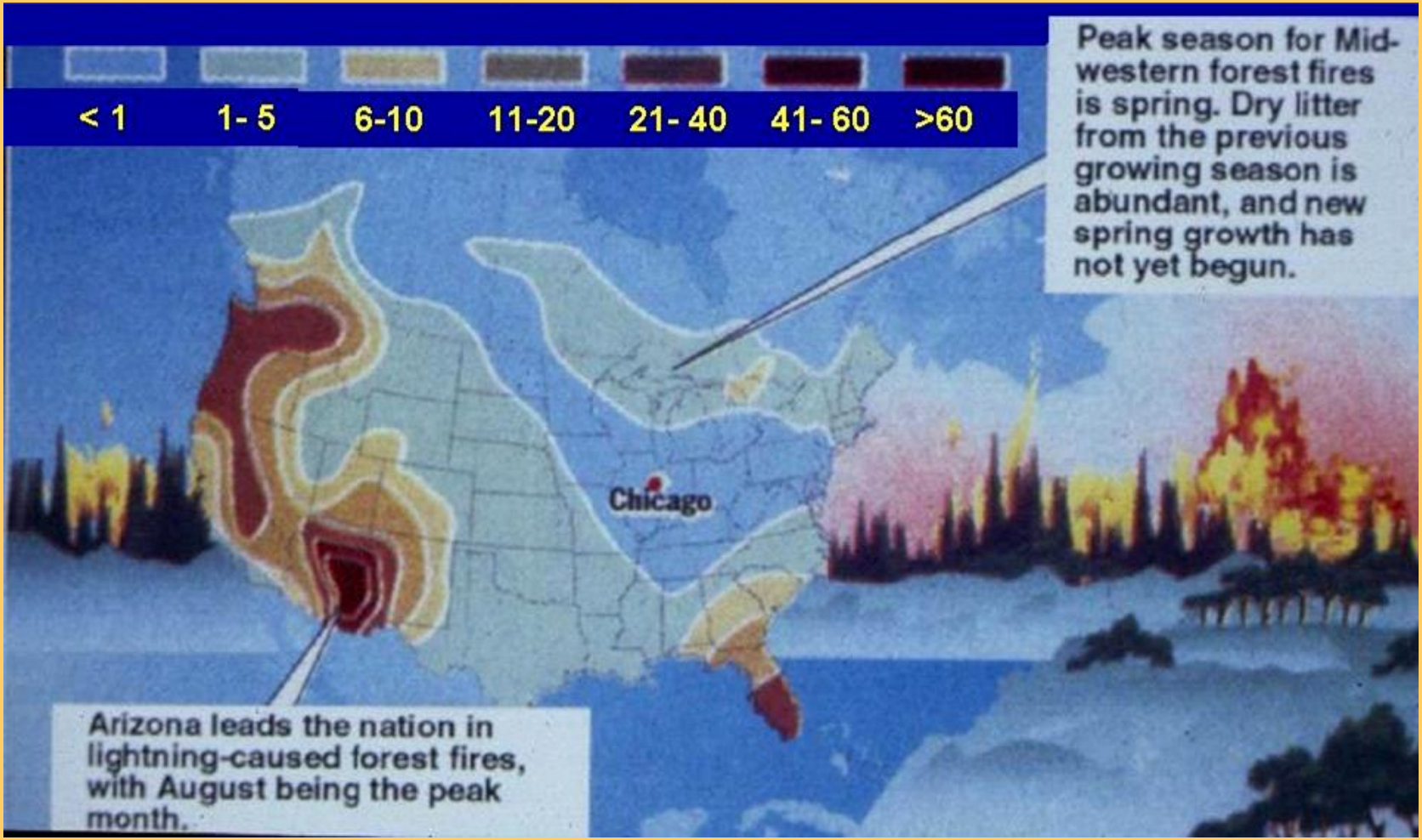


10	20	30	40	(Inches)

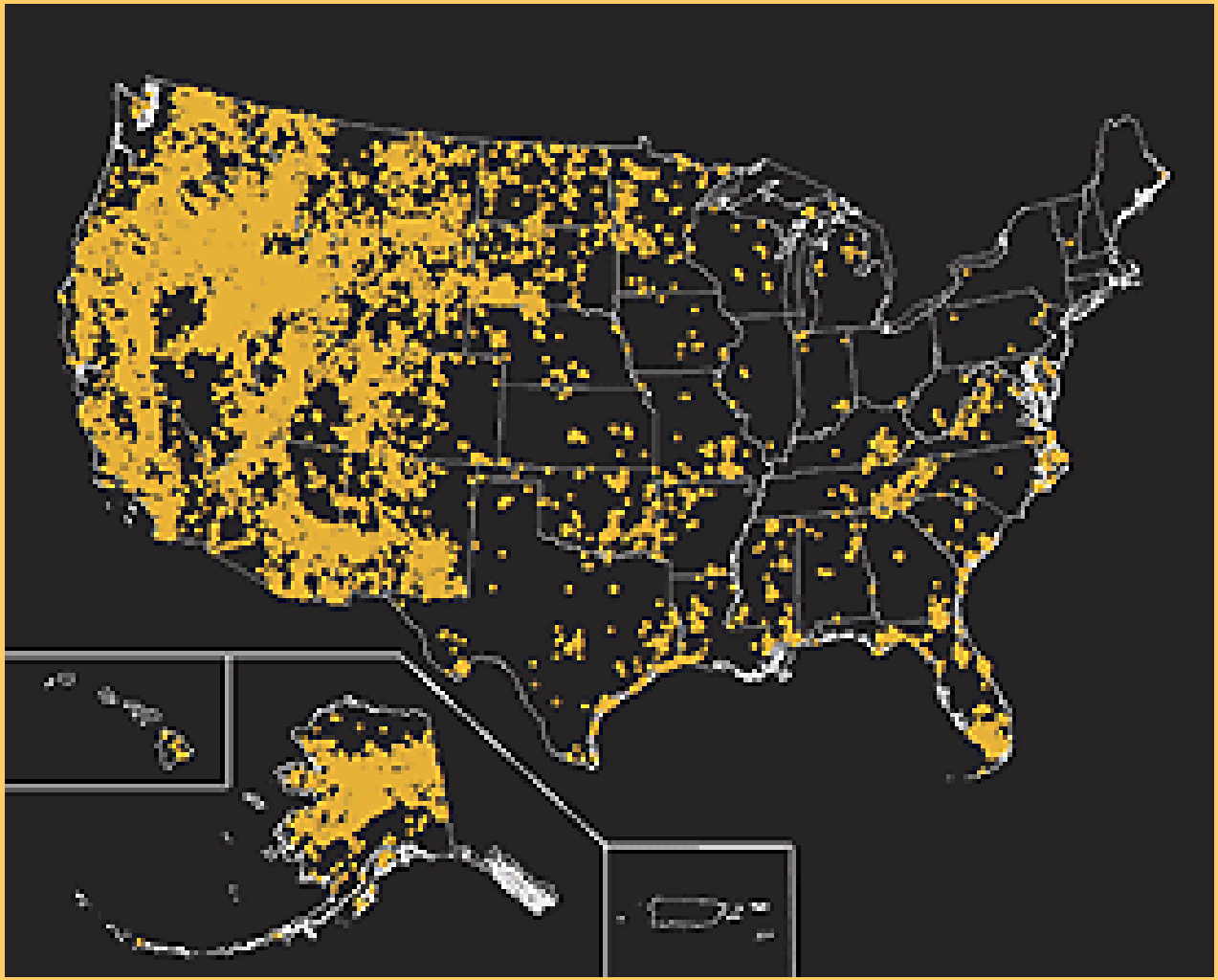
Why does burning increase productivity of tallgrass prairie?

Average Annual Number of Lightning Caused Forest Fires Per Million Acres

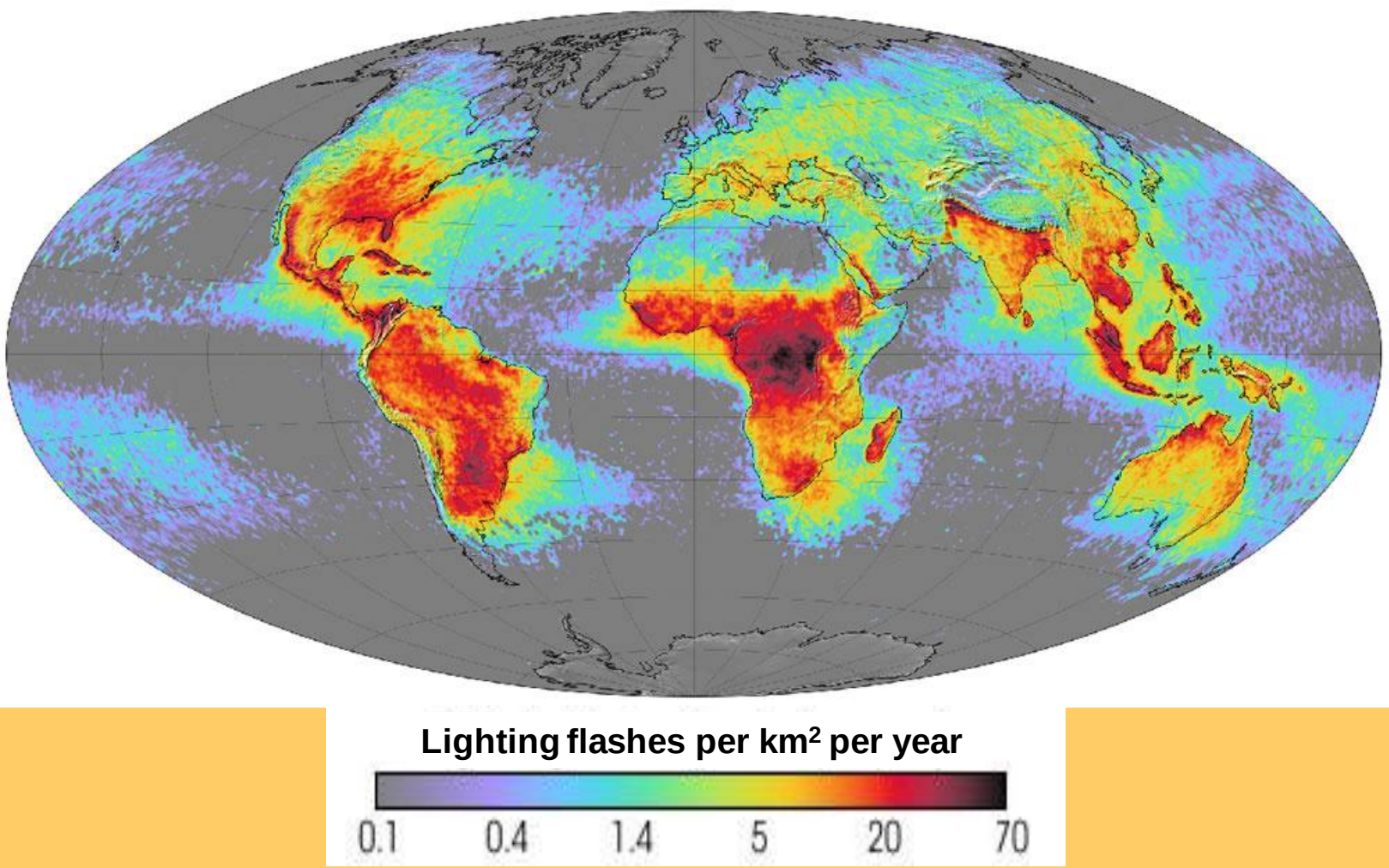
Ignition Source of Prairie Fires



Fires on Natural USA Land 1980-2003



Average yearly counts of lightning flashes per sq. km based on data collected by NASA satellites between 1995 and 2002.



Plant Diversity on the tallgrass prairie

•C4 grasses are the dominant species

•Forbs contribute most species richness

- Many forbs are C3 plants
- Frequent burns can reduce the abundance of forbs

Bison diet is 90-95% Grass, they consume few forbs, and they can offset effects of frequent burns

Key Features of Bison Grazing

- **Diet Primarily 90-95% grass**
- **Graze in two patterns**
  - **Extensive grazing lawns > 400 m^2**
  - **Grazing patches 20-50 m^2**
- **Prefer previous grazed to ungrazed sites**
  - **Higher nitrogen**
  - **More palatable**
  - **No dead tissue**

Production on grazed and ungrazed patches

- **Initially photosynthesis is higher on grazed patches**
  - **Physiologically younger tissue**
  - **Higher nitrogen**
  - **More moisture**
  - **Higher light**
- **Eventually production declines on grazed patches**
  - **Nitrogen withdrawn from belowground**
- **Repeated grazing selects for non-palatable species**
  - **Encourages shifting to other areas**
  - **6-7% of patches abandoned each year**


Non-palatable forb –
Prairie Bushclover

Affects nutrient Cycling

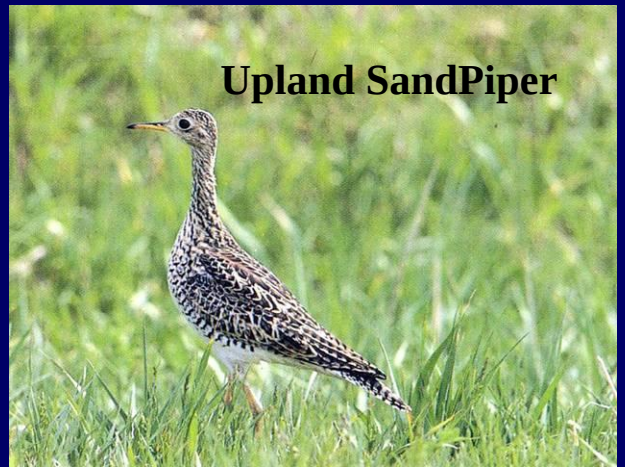
- **Grazing offsets nitrogen loss with burning**
  - **Less litter to burn**
- **Reduces microbial immobilization of nitrogen**
  - **Litter has lower C:N ratio**
- **Grazing increases plant uptake of nitrogen**
  - **Increases the rate of mineralization of organic nitrogen (Urea to Ammonia)**

Enhance Habitat Diversity

- **Reduces fire intensity and makes patchy fires**
  - **Favors fire sensitive species (e.g. Insects)**
- **Increases spatial heterogeneity**
  - **Increases bird diversity**

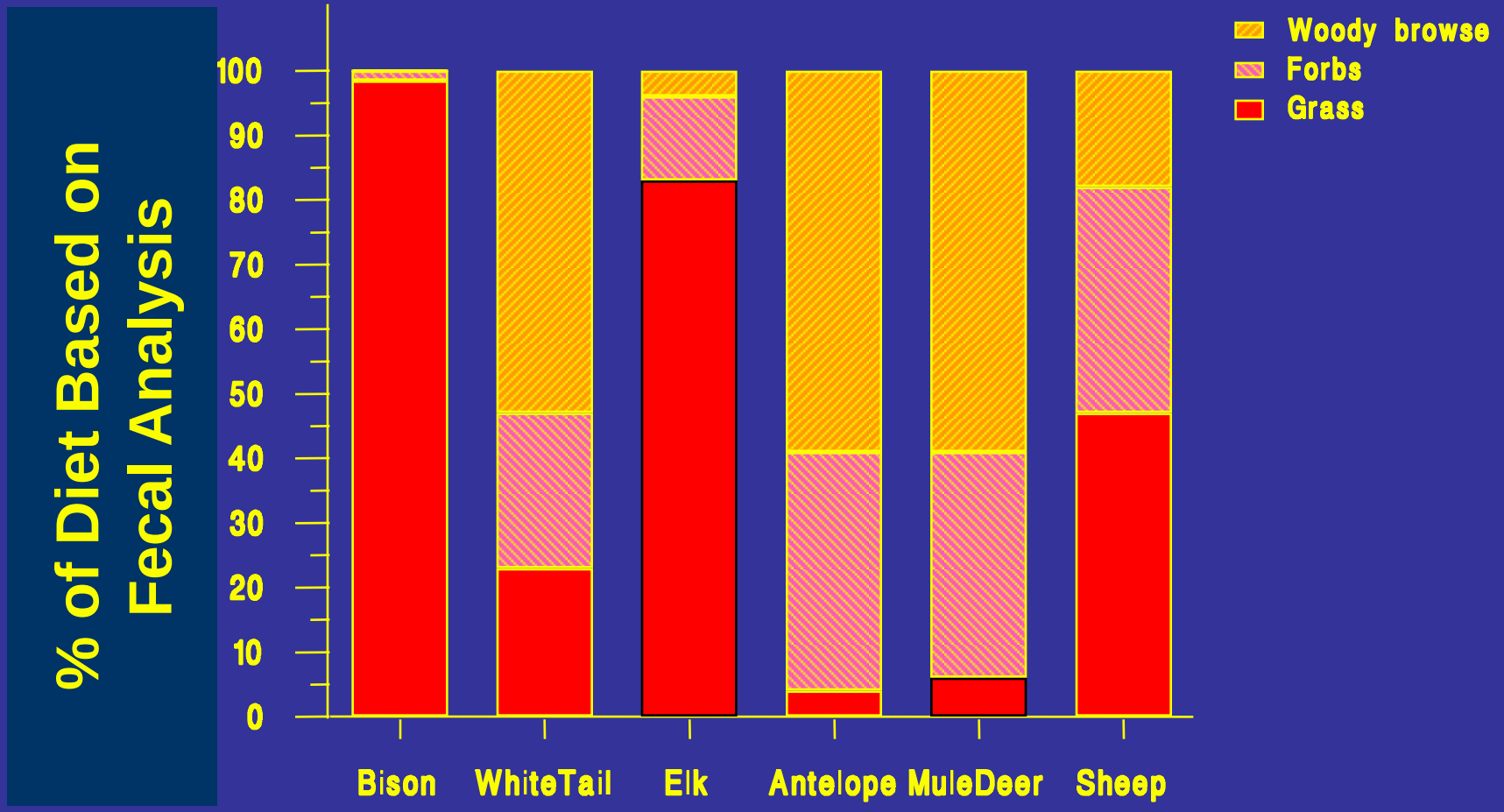
Bison can increase Bird Diversity

- Grassland birds require a continuum of habitats from short grass with bare spaces to dense tall grass
- Bison can provide that continuum



Upland Sand Piper Midewin National Tallgrass Prairie

Niche Separation in Ungulates



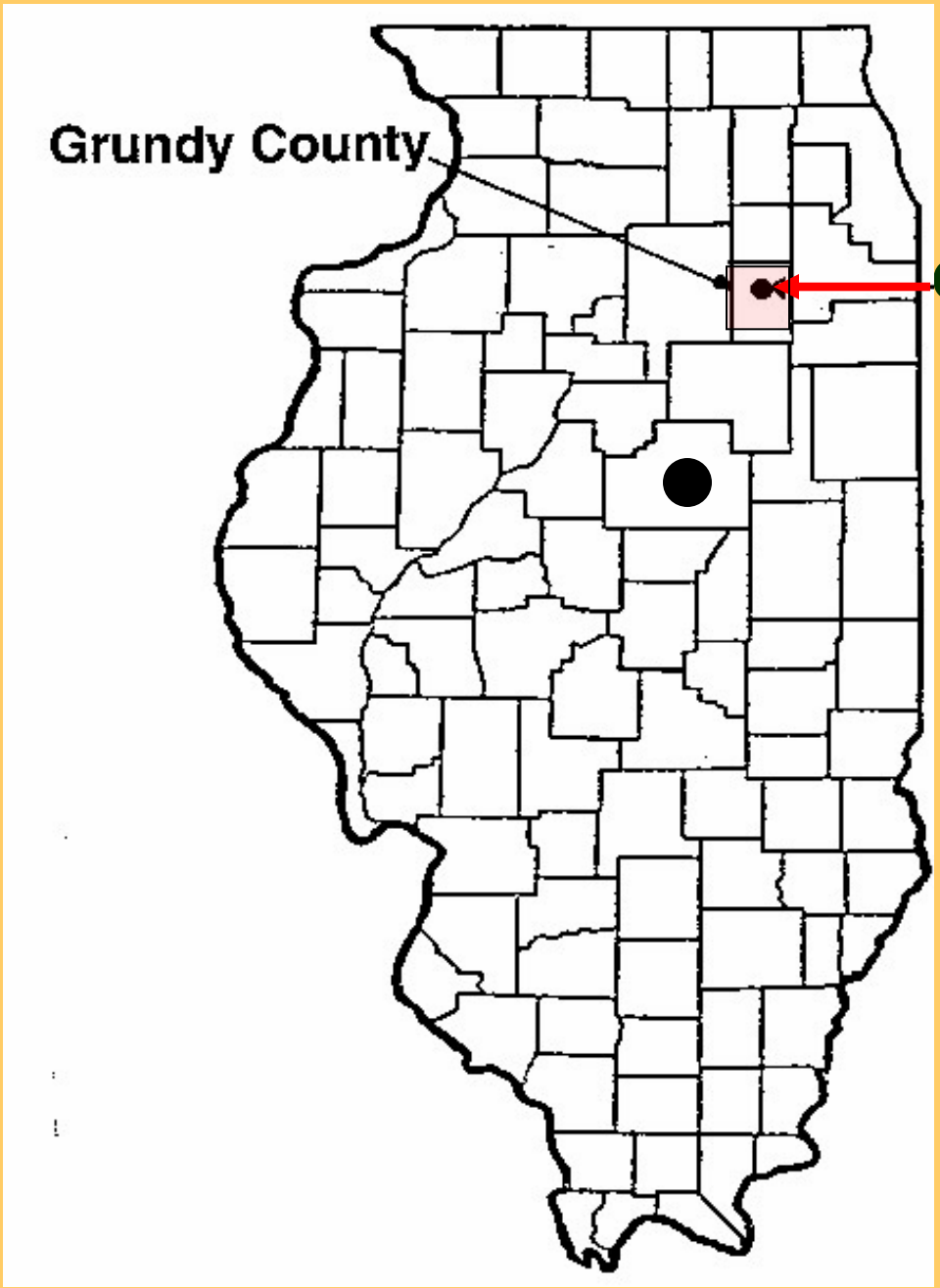
Modified from McCullough, 1980

Influence of White-tailed Deer Browsing on Tallgrass Prairie

Questions We Asked

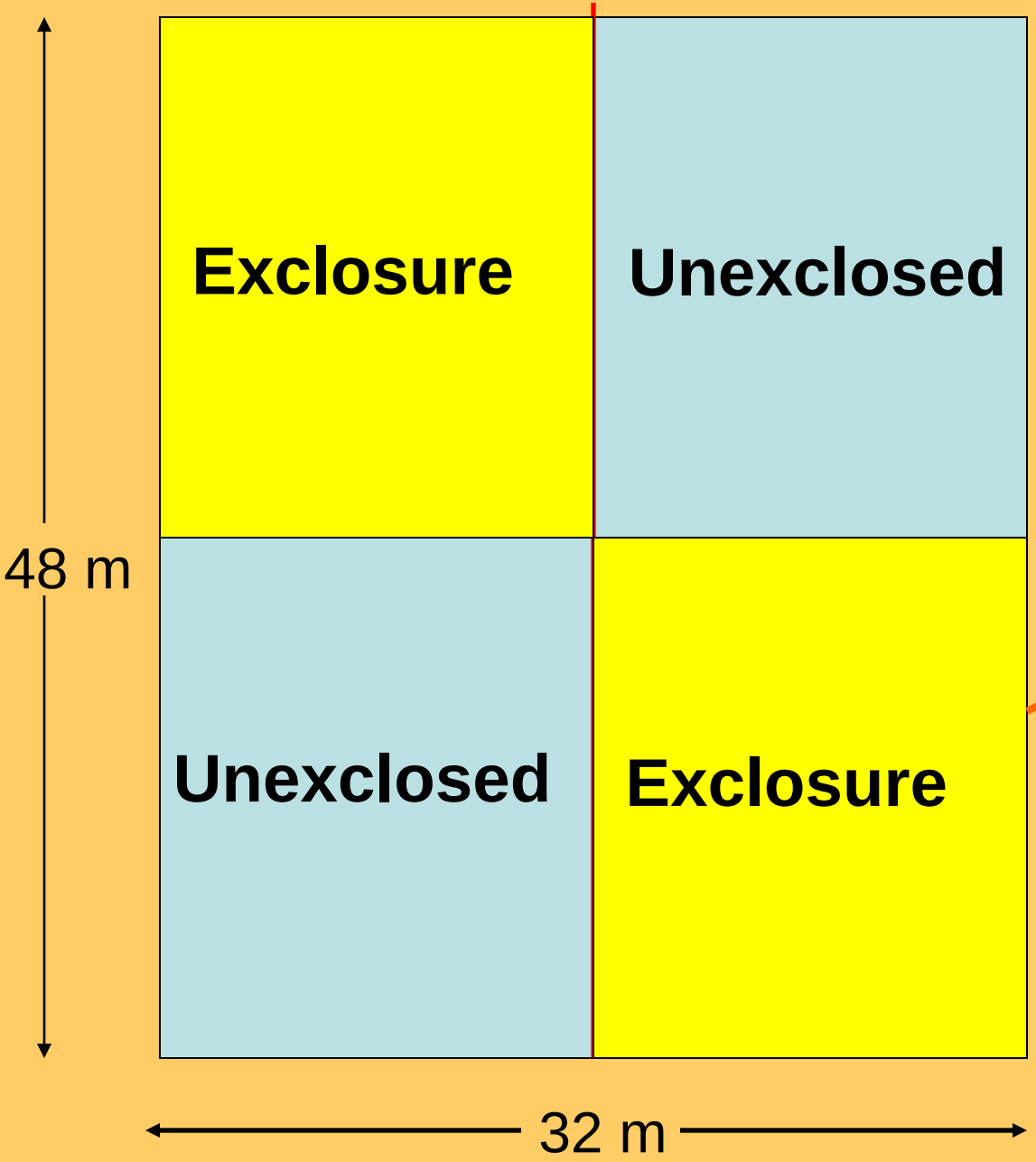
- How did species of forbs respond to browsing?
- How was forb diversity affected by deer browsing?
- How was floristic quality affected by deer browsing?
- How did deer browsing and burning affect flowering

Location of study area

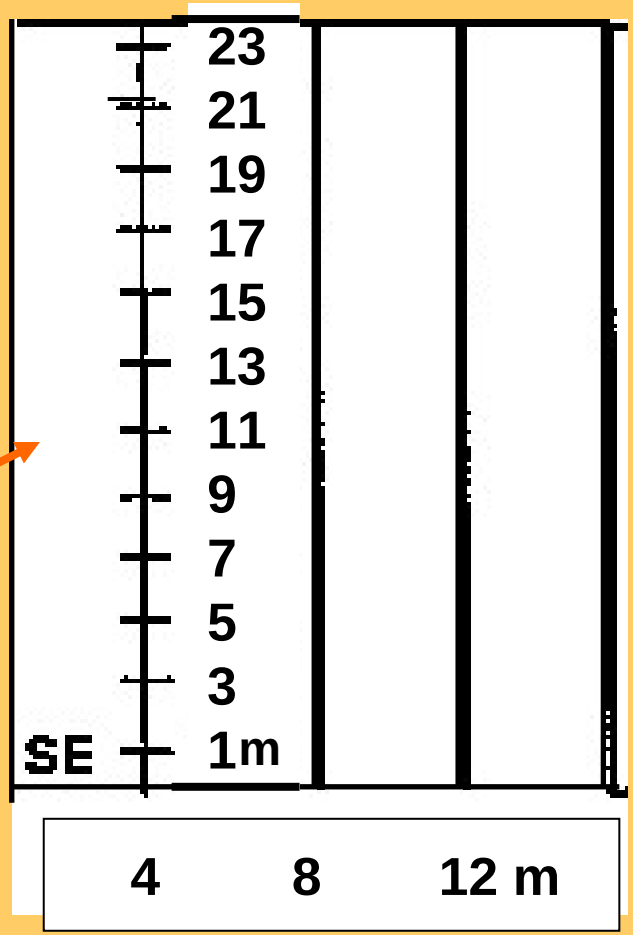


Goose Lake Prairie State Park

Study Design

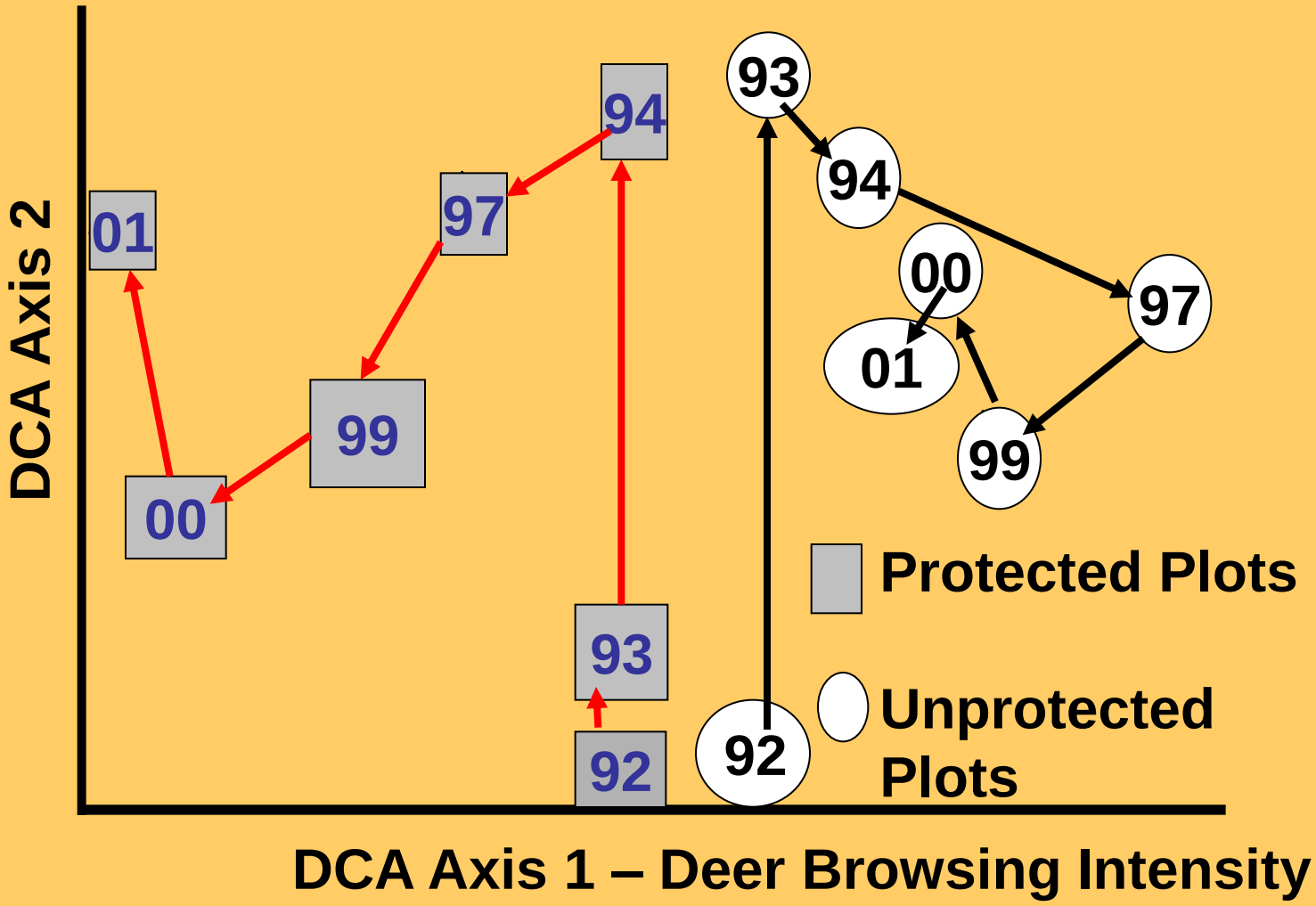


Sampling Forbs and Graminoids

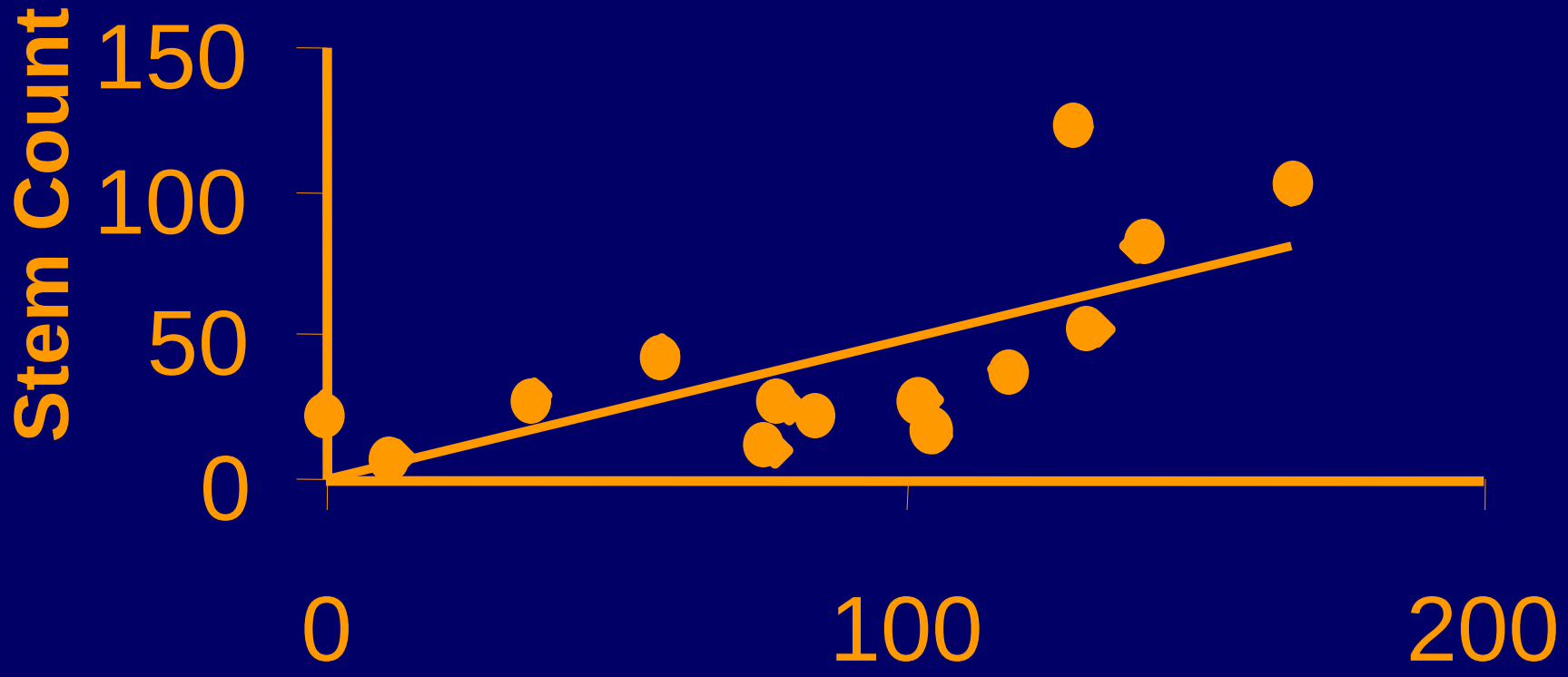


Local deer density by year

Year	deer/km^2
1992	32
1993	50
1994	34
1995	32
1996	32
1997	No count - hunting in fall
1998	9
1999	7


DCA Axis 2
01
97
94
99
00
93
92
93
94
00
97
01
99
Protected Plots
Unprotected Plots
DCA Axis 1 – Deer Browsing Intensity

Solidago canadensis



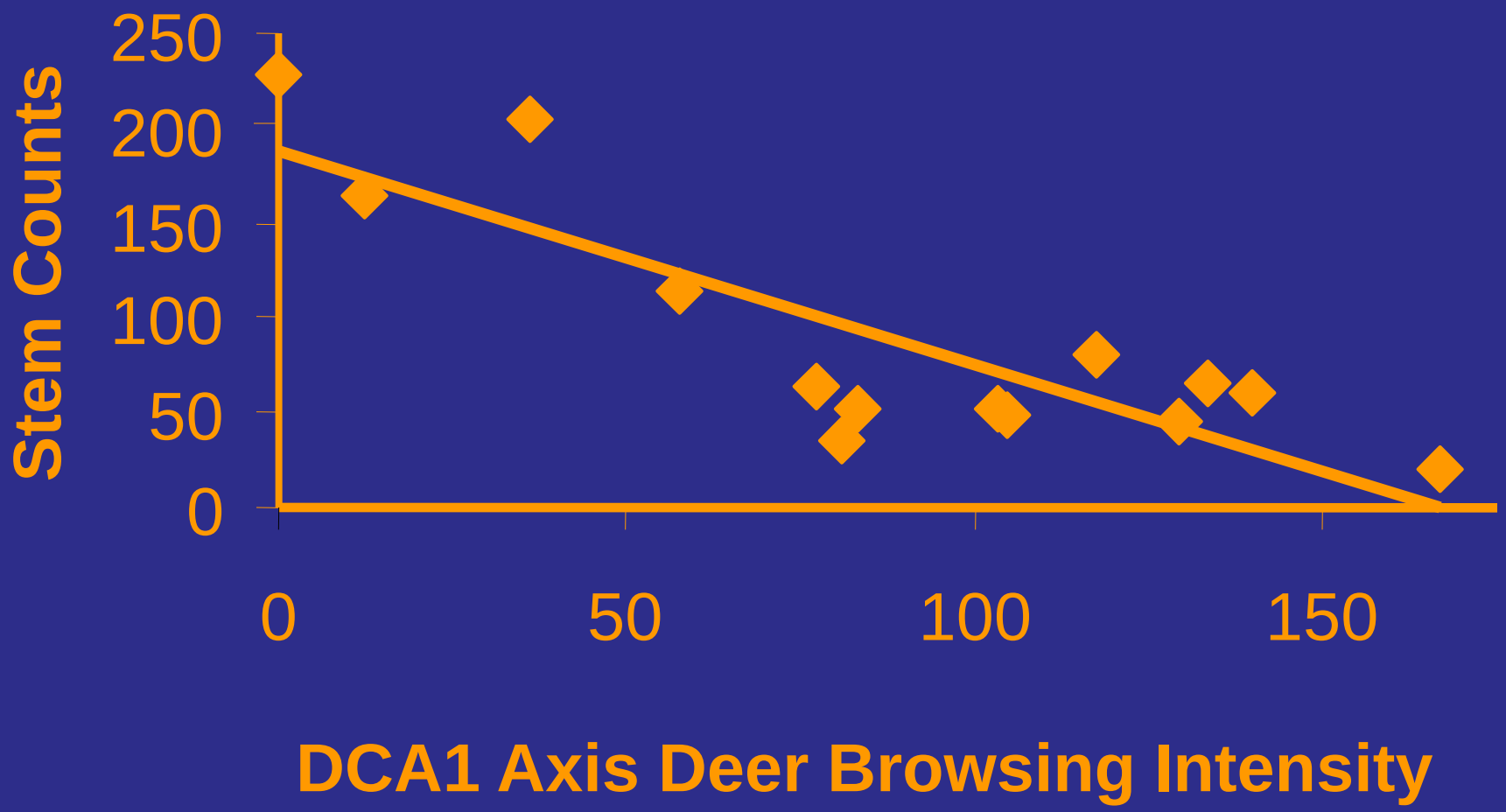
DCA1 Axis Deer Browsing Intensity

Species Responding Positively to intense deer browsing

Species	Correlation Coefficient
Monarda fistulosa	**+ 0.736****
Heuchera richardsonii	**+ 0.706****
Solidago canadensis	**+ 0.678****
Silphium integrifolium	**+ 0.634***
Amorpha canescense	**+ 0.572***

- **P<0.05, r= 0.532, P<0.01, r= 0.661**

Veronicastrum virginicum

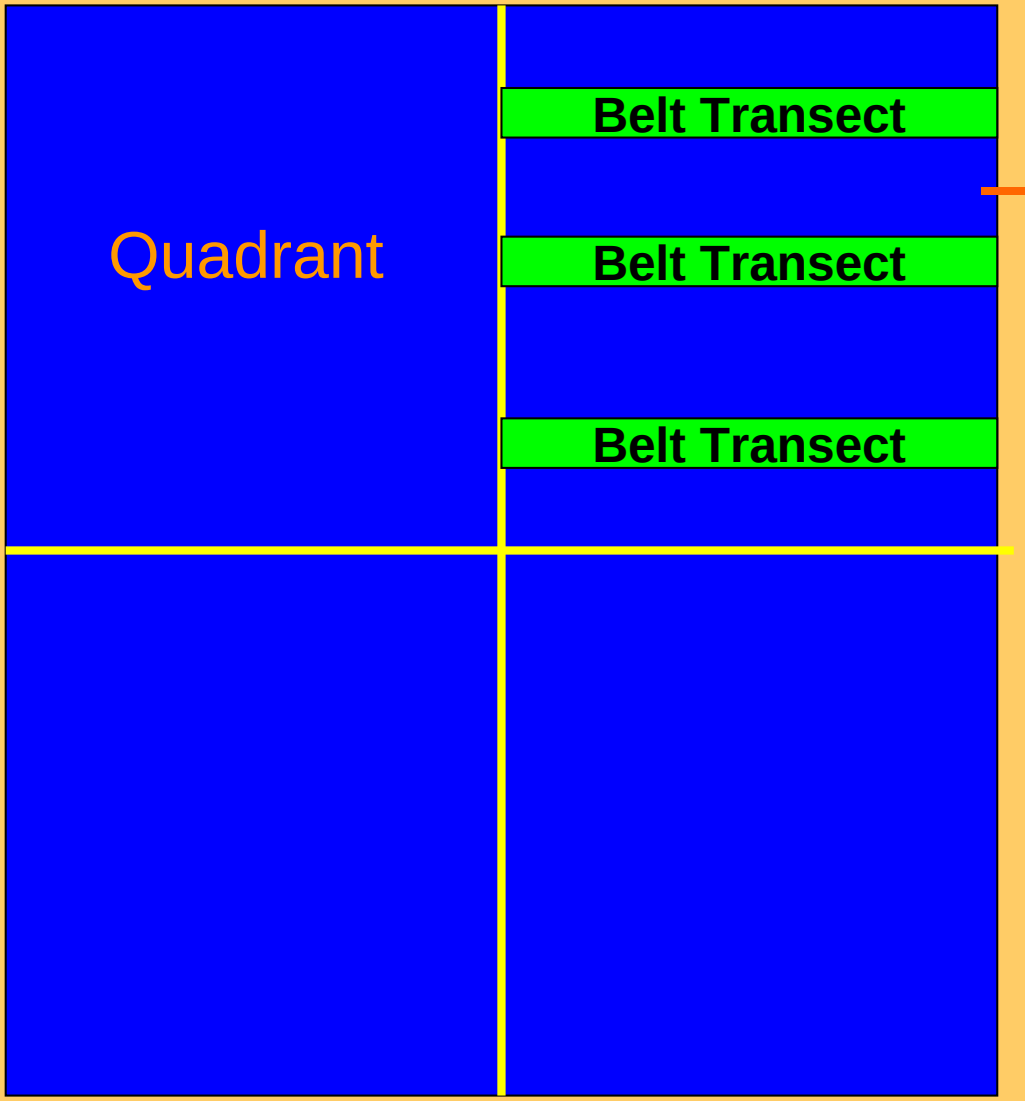


Species Responding Negatively to intense deer browsing

Species	Correlation Coefficient
Tradescantia ohiensis	- 0.871**
Veronicastrum virginicum	- 0.847**
Commandra richardsonii	- 0.826**
Helianthus mollis	- 0.768**
Stachys palustris	- 0.700**
Aster azerus	- 0.700**
Rosa carolina	- 0.654**
Rudbeckia subtomentosa	- 0.552*

- P<0.05, r = 532. P<0.01, r = 0.661

Effect of Deer Browsing and Fire on Flowering



Three Belt Transect Per Transect

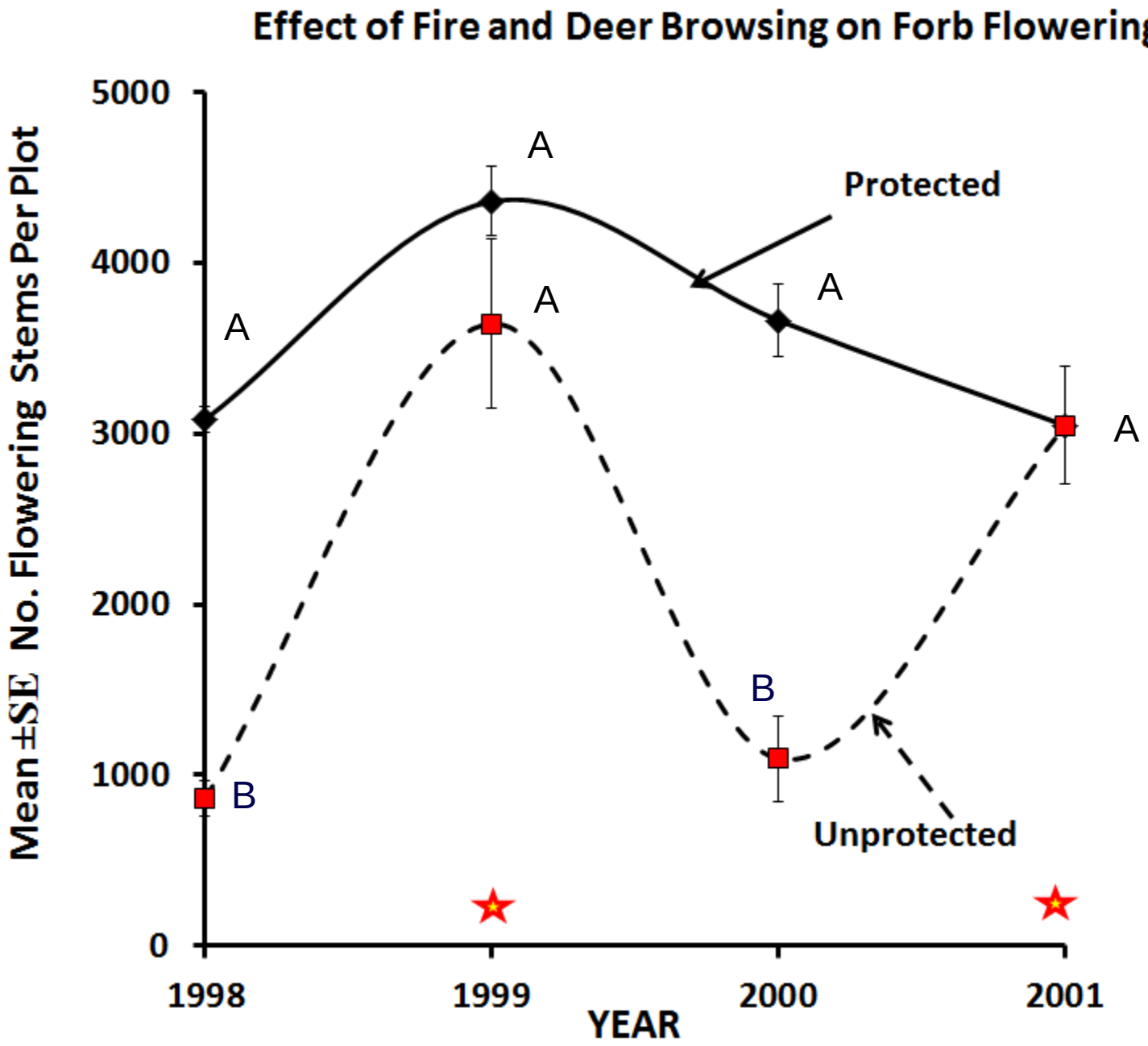
2 m x 12 m

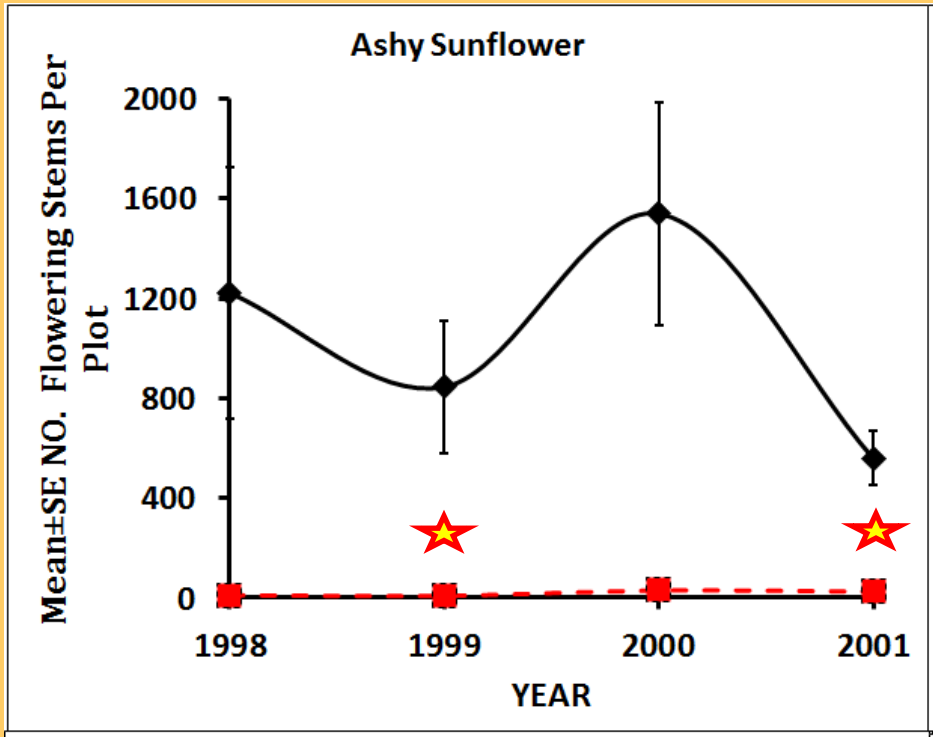
Counted Number of stems by species bearing buds, flowers, or fruits

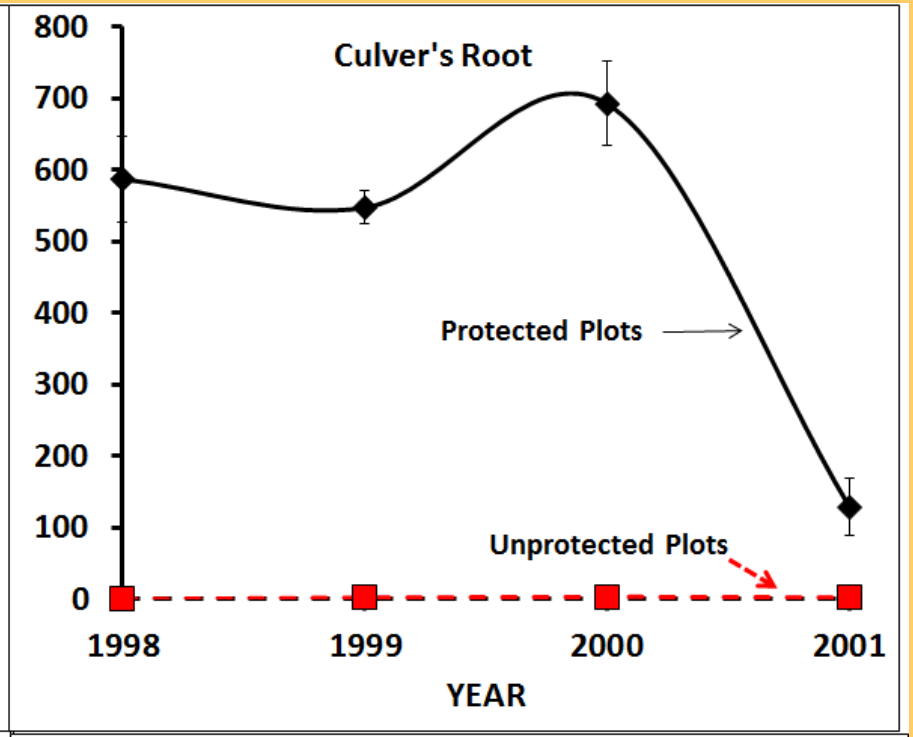
Leading Species on Study Plots

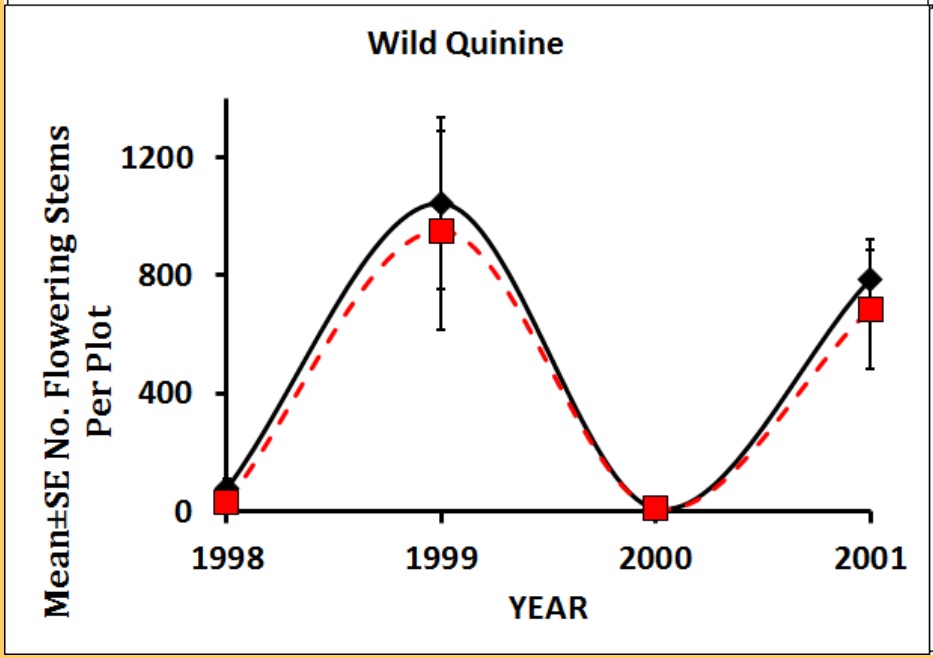
Unprotected	Total Count*
• Rosinweed (*Silphium integrifolium*)	9052
• Wild Quinine (*Parthenium integrifolium*)	3462
• Early Goldenrod (*Solidago juncea*)	2043
Protected	
• Ashy sunflower (*Helianthis mollis*)	5637
• Culver's Root (*Veronicastrium virginicum*)	3908
• Wild Quinine (*Parthenium integrifolium)*	3839
• Rosinweed (*Silphium integrifolium*)	3251
• Spiderwort (*Tradescantia ohiensis*)	2248
• Early Goldenrod (*Solidago juncea*)	1832
• Sweet Black-eyed Susan (*Rudbeckia subtomentosa*)	1342

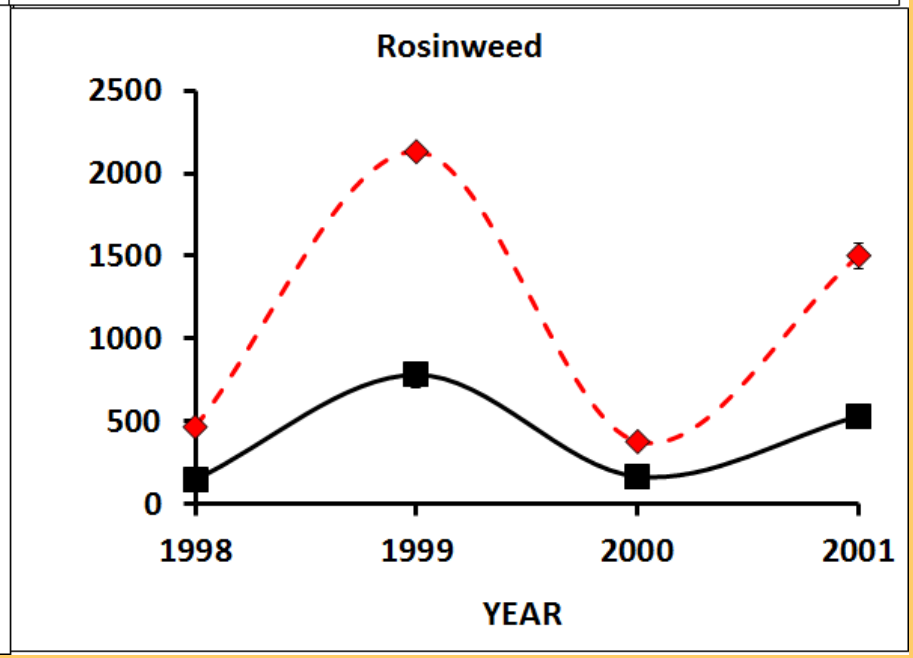
*Species with more than 1,000 flowering stems counted on either the protected or unprotected plot during the study are included in the list of leading species.


Effect of Fire and Deer Browsing on Forb Flowering
Mean ±SE No. Flowering Stems Per Plot
5000
4000
3000
2000
1000
0
1998
1999
2000
2001
YEAR
Protected
Unprotected
A
A
A
A
B
B

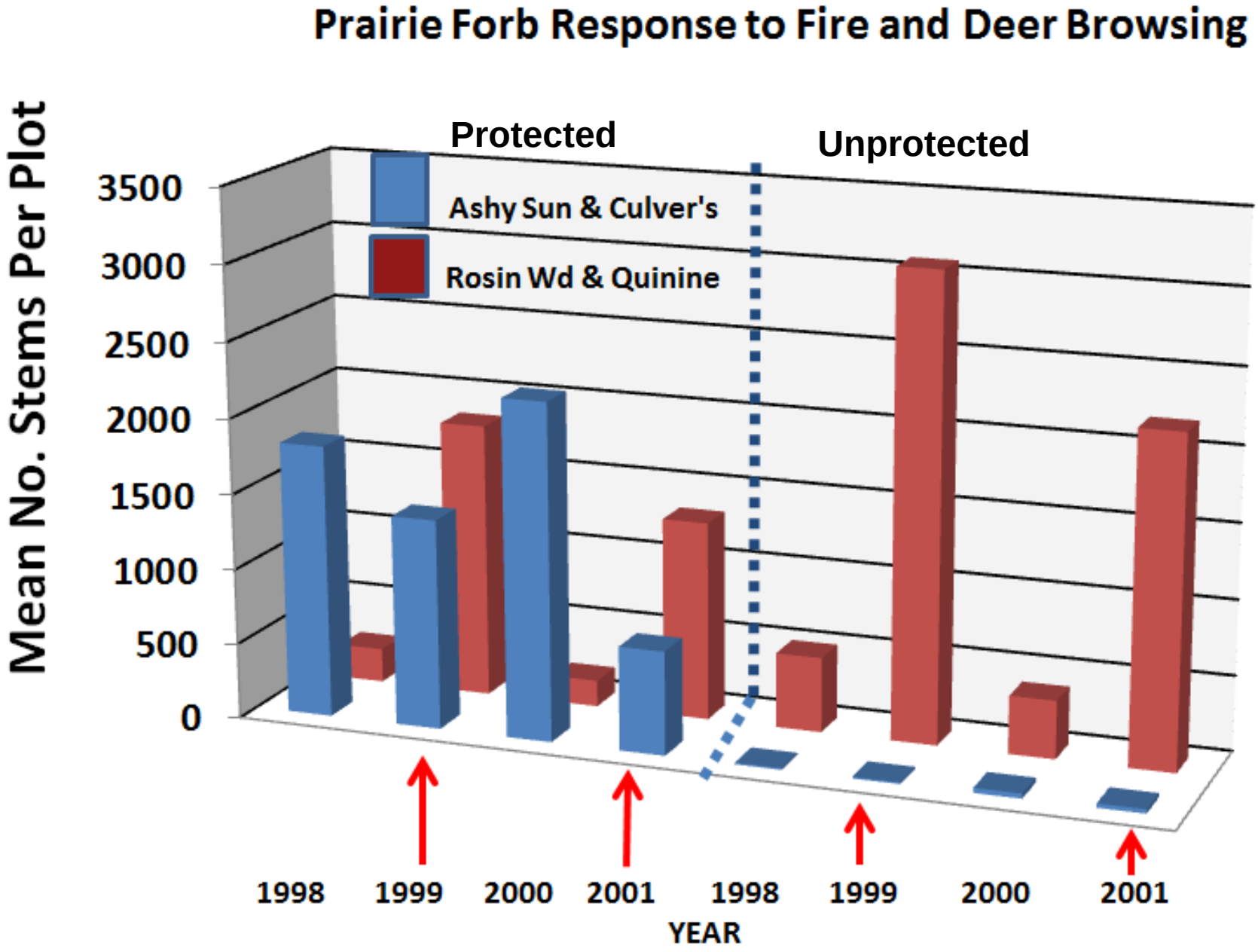

Ashy Sunflower
Mean±SE NO. Flowering Stems Per Plot
2000
1600
1200
800
400
0
1998
1999
2000
2001
YEAR


Culver's Root
800
700
600
500
400
300
200
100
0
Protected Plots
Unprotected Plots
1998
1999
2000
2001
YEAR


Wild Quinine
Mean±SE No. Flowering Stems Per Plot
1200
800
400
0
1998
1999
2000
2001
YEAR


Rosinweed
2500
2000
1500
1000
500
0
1998
1999
2000
2001
YEAR

Snout-beetle Rhynchites hirtus **feeds on rosinweed inflorescences**


Prairie Forb Response to Fire and Deer Browsing
Protected
Unprotected
Ashy Sun & Culver's
Rosin Wd & Quinine
Mean No. Stems Per Plot
3500
3000
2500
2000
1500
1000
500
0
1998
1999
2000
2001
1998
1999
2000
2001
YEAR

Species Richness

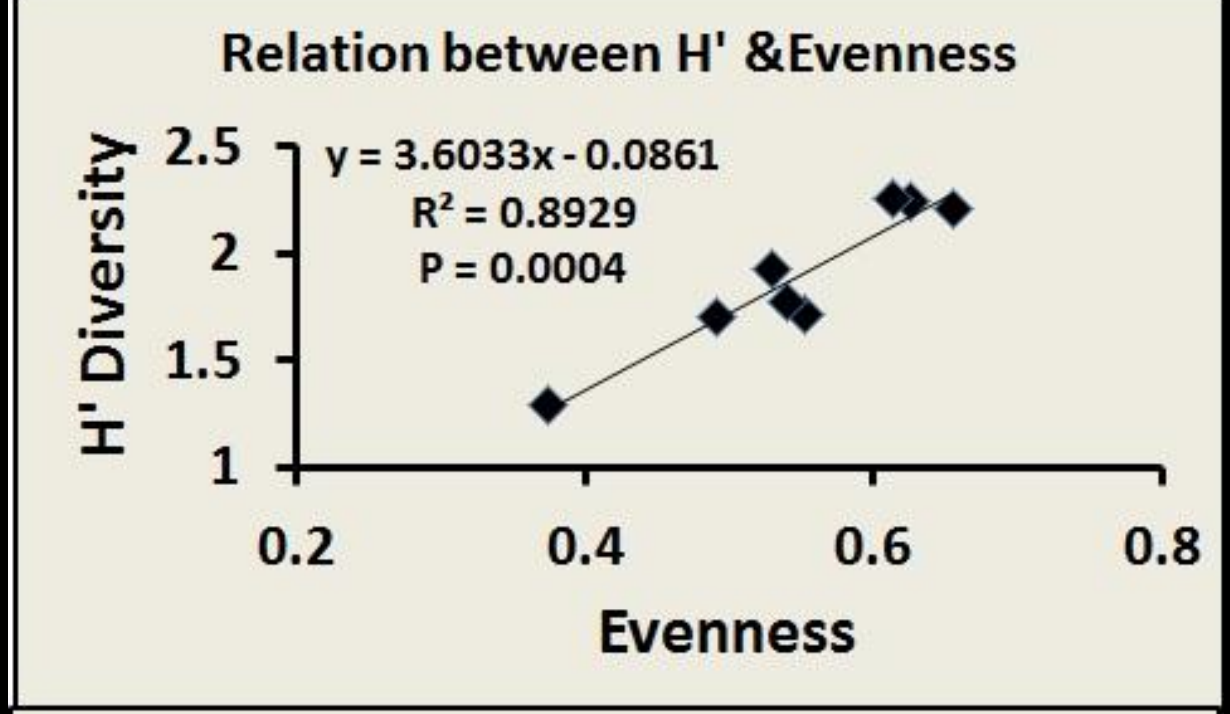
Year level	Protected	Unprotected	χ^2	P-
1998	29	22	0.960	p>0.1
1999	36	31	0.373	p<0.9
2000	38	26	2.250	p>0.1
2001	40	32	0.888	p<0.5

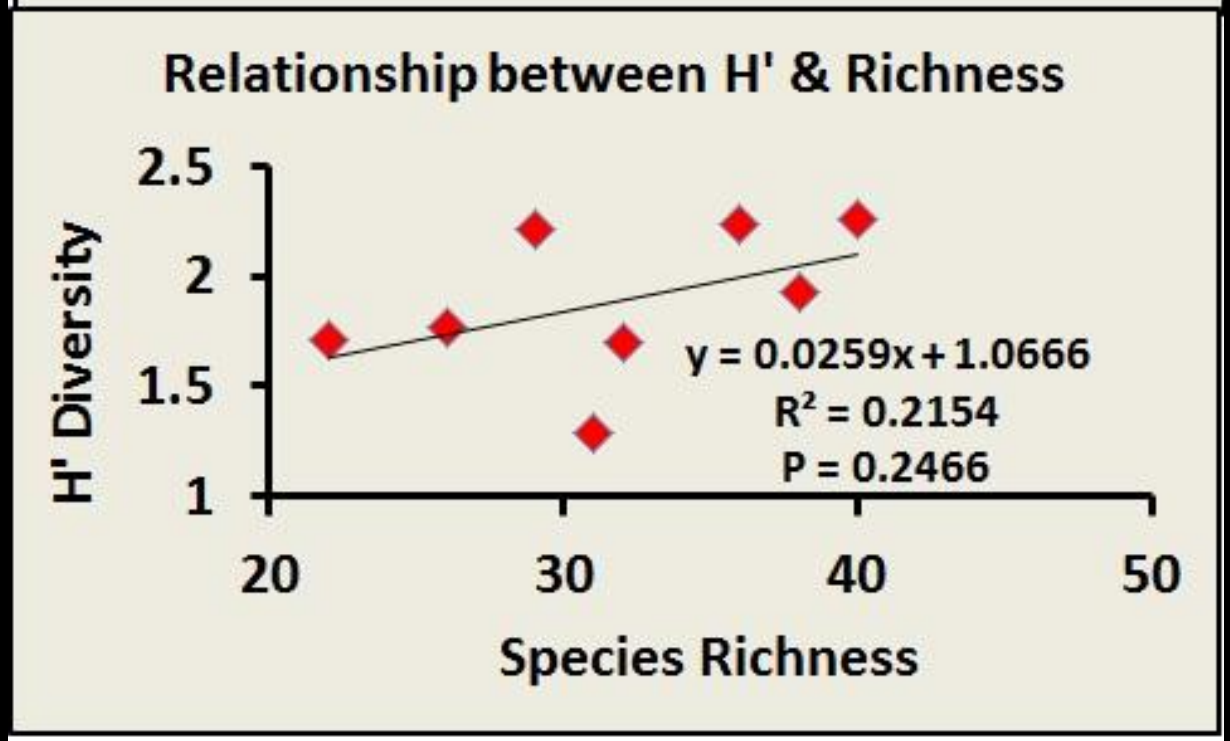
Evenness

Year	Protected	Unprotected	χ^2	P-Level
1998	0.656	0.553	0.931	p<0.5
1999	0.625	0.374	6.306	p<0.025
2000	0.530	0.540	0.009	p>0.90
2001	0.614	0.491	2.245	p>0.10

Shannon Diversity Index H’

Year	Protected	Unprotected	P-level
1998	2.21	1.70	P<0.001
1999	2.24	1.28	P<0.001
2000	1.92	1.77	p<0.001
2001	2.26	1.70	p<0.001


Relation between H' &Evenness
y = 3.6033x - 0.0861
R² = 0.8929
P = 0.0004
H' Diversity
2.5
2
1.5
1
0.2
0.4
0.6
0.8
Evenness


Relationship between H' & Richness
y = 0.0259x + 1.0666
R² = 0.2154
P = 0.2466
H' Diversity
2.5
2
1.5
1
20
30
40
50
Species Richness

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